Effect of Varying Dietary Protein:Lipid Ratios on Growth and Body Composition of Coho Salmon Fry *(Oncorhynchus kisutch)* Reared at Different Temperatures

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December 1982

Canadian Data Report of Fisheries and Aquatic Sciences No. 373

Canadian Data Report of Fisheries and Aquatic Sciences

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Canadian Data Report of

Fisheries and Aquatic Sciences 373

December 1982

EFFECT OF VARYING DIETARY PROTEIN:LIPID RATIOS ON GROWTH AND BODY COMPOSITION OF COHO SALMON FRY (*Oncorhynchus kisutch*) REARED AT DIFFERENT TEMPERATURES

by

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Cat. No. Fs 97-13/373 ISSN 0706-6465

ABSTRACT

Clarke, W. C., D. A. Higgs, J. R. Markert, J. E. Shelbourn, and A. J. Castledine. 1982. Effect of varying dietary protein:lipid ratios on growth and body composition of coho salmon fry (Oncorhynchus kisutch) reared at different temperatures. Can. Data Rep. Fish. Aquat. Sci. 373: iv + 18 p.

This report shows the effects of varying protein:lipid ratios in a practical dry diet on growth and body composition of juvenile coho salmon held at temperatures from 7 to 19°C. The experiment involved 34 groups of approximately 100 fry in a 3-factor composite factorial design. Two additional groups of fry were fed Oregon Moist Pellets for comparison. The study was conducted in two parts in successive years. The diets were fed for approximately 9 wk each year.

Data are presented for composition of test diets, proximate composition of diets and of fish carcasses, mortality, initial and final wet weights, specific growth rates, dry weight gain and feed conversion, protein, lipid and energy utilization, and whole body fatty acid composition of neutral lipid and phospholipid.

Key words: coho salmon, diet, protein, lipid, temperature, food conversion.

RÉSUMÉ

Clarke, W. C., D. A. Higgs, J. R. Markert, J. E. Shelbourn, and A. J. Castledine. 1982. Effect of varying dietary protein:lipid ratios on growth and body composition of coho salmon fry (Oncorhynchus kisutch) reared at different temperatures. Can. Data Rep. Fish. Aquat. Sci. 373: iv + 18 p.

Nous voulons présenter ici les effets de la variation parmi les raports protein:lipide dans un régime sec sur la croissance et la composition du corps entier des saumons coho jeunes, contenus dans l'eau aux temperatures entre 7 et 19°C. L'expérience a été constitué de 34 groupes, chacun de presque 100 alevins, soumis au dessin statistique factorial de 3 facteurs. Par comparison, 2 groupes d'alevins ont été nouris de Oregon Moist Pellets. L'e périence a été conduite à deux parties par ans consecutifs. On a donné cette nouriture aux alevins pendant 9 semaines à chaque instance.

Nous présentons les données quant au composition de régime expérimental: au composition approximative des régimes et du corps entier des poissons: à la mortalité: aux taux spécifique de croissance: à l'augmentation de poids sec du corps: aux usages de protein, lipide, et énergie: et, enfin, au composition du corps entier en réspect des lipides neutrales et de phospholipide.

INTRODUCTION

This report provides background information and results of an investigation of the effects of varying dietary protein:lipid ratios on growth, food conversion, protein utilization and body composition in coho salmon fry reared at temperatures of 7-19°C.

METHODS

The experiment involved 36 separate culture tanks and, because of spatial limitations, was conducted over 2 yr, 1979 and 1980.

A. STOCK

The 1979 stock were raised from fry obtained from Quinsam Hatchery (B.C.) stock. They were brought to the Pacific Biological Station, Nanaimo, B.C. (PBS) and were fed on the Oregon Moist Pellet diet (OMP; Moore Clarke Co., Laconner, WA) until selection for distribution to the experimental tanks. The 1980 fish were raised from eggs obtained from adults returning to the experimental fish farm at PBS (originally from Big Qualicum stock), and were reared similarly to the 1979 stock.

B. DISTRIBUTION AND SAMPLING

The methodology was similar in 1979 and 1980, and the following description is applicable to both.

Fry were selected for uniform size in mid-April (1979, 1.19 g, sd = 0.14; 1980, 1.69 g, sd = 0.24) and randomly distributed among 197-L indoor experimental tanks, in groups of approximately 100. Artificial lighting was cycled to approximate natural photoperiod while temperature acclimation was achieved at the rate of 1°C per day. Maintenance rations were fed for 2 wk before the experiment started, when the fish were anaesthetized and weighed to establish the start of the growth response. During the test period fish were fed thrice daily to measured satiation with the test diets (twice on weekends), and were anaesthetized and weighed bi-weekly, after 24-h starvation. Water temperature was maintained by the appropriate mixing of laboratory supply lines, while temperatures were checked by daily thermometer readings.

C. ANALYTICAL METHODS

At the time of final weighing in the first year, 1979, 6 samples of 3 fish each were analyzed for lipid content, extraction being made by the method of Folch et al (1957).

Polar lipids and neutral lipids were separated by silicic acid column chromatography. Fractions were checked for cross contamination by thin layer chromatography. Fatty acid methyl esters were prepared in 0.5 N sodium methoxide as described by Christie (1973).

Separation and quantification of methyl esters were accomplished by gas-liquid chromatography (Model 3700 FID, Varian Inc., Palo Alto, CA) on a 2 M: x 2 mm stainless steel column packed with 3% EGSP-Z on 100/120 mesh Gas Chrom Q (Supelco, Inc., Bellefonte, PA). Peak areas were determined automatically using a microprocessor (Model CDS 111, Varian); methyl esters were identified with the aid of authentic standards (Supelco) or by the procedures of Ackman (1963).

Analysis conditions:

Temperatures:	Injector	220°C	Flow rates:	Air	300 cc/min
	Detector	270°C		Nitrogen	30 "
	Column	190°C		Hydrogen	30 "

Phospholid phosphate was determined by the procedure of Bartlett (1959) following perchloric acid digestion. There were no differences due to dietary treatment and, similar to rainbow trout, phospholipid represented 1% of wet body weight (Castledine and Buckley, 1980).

Samples were taken for proximate analysis, at both the start and end of the experiment. The procedures of Higgs et al. (1979) were used to determine, in duplicate, the proximate composition of weighed fractions of homogenized fish. Total nitrogen was multiplied by 6.25 to obtain crude protein. Diets were analyzed using similar procedures.

D. EXPERIMENTAL DIETS

Ten dry diets (< 10% moisture) were prepared for this study; the one at the center of the experimental design was common in 1979 and 1980 (Table 1a and b). Diets were formulated to contain protein at 32, 42 or 52% and lipid at 8, 13, and 18% of dry matter. Table 3 shows the measured protein and lipid contents in each of the diets. Mean estimated dietary metabolizable energy contents corresonding to low, medium and high lipid levels, were 3.7, 3.9 and 4.1 kcal/g respectively, regardless of protein level (Table 3). All diets

were formulated to have a similar balance of essential amino acids by adjusting proportionately the levels of all protein sources (not done for shrimp meal in 1979) and by supplementing diets with varying amounts of DL-methionine. Similar mineral levels were maintained in all diets (Table 4) by analyzing all protein sources for mineral content (Higgs et al. 1982) and then adjusting the composition of the dietary mineral supplement accordingly (Table 2). Preparation of each test diet involved addition of varying amounts of water to the mash (< 3.2%) before cold pelleting using a California model CL-type 2 laboratory pellet mill, crumbling, and then screening to obtain correct particle size in relation to fish size. Other aspects of diet preparation have been described previously (Higgs et al. 1979). All diets were stored at 4°C.

E. EXPERIMENTAL DESIGN

Since a replicated three-level, three-factor design with three centre points would have required 58 tanks, a composite design with the same statistical power was chosen (Alderdice and Thomson, 1974). This needed only 34 tanks: the treatments assigned, the measured temperature levels and the tank stock sizes are shown in Table 5.

F. FISH HEALTH

There were no obvious signs of disease. Appetite was always good, and mortalities negligible (Table 5).

DATA

Wet weight means and specific growth rates (daily logarithmic increment) are shown in Table 6 for the replicate pairs (labelled 1 and 2 throughout the tables). Differences in laboratory timetables resulted in a slightly different length of the experimental period between the 2 y (indicated in the final column of the table).

Proximate analyses of initial and final samples of fish are shown in Table 7. Where samples apply to more than one treatment combination at the beginning (i.e. where temperature was the only difference between tanks at that time) duplications are omitted and are replaced by dashes.

Average dry weight gain, dry food intake and food conversion are shown in Table 8.

Three measures of protein utilization are shown in Table 9.

Computations are based on the mean initial and final fish weights and the feed intake divided by the final n for the tank. Apparent net protein utilization, ANPU, is the ratio of protein gain to protein ingested as a percentage (Zeitoun et al, 1973). Protein efficiency ratio, PER, is the ratio of dry weight gain to weight of protein ingested (ibid.). Lastly, gain in protein is expressed as an index of gain per unit of metabolizable energy ingested. (Metabolizable energy was estimated using the caloric equivalents listed in Table 3, footnote d.)

Table 10 shows similarly the relationship of lipid gain to lipid consumed or lipid conversion (cf. ANPU, Table 9). The energy utilization, EU relates the caloric gain by the fish (calculated assuming 5.7 kcal/g protein, 9.5 kcal/g lipid and 4.0 kcal/g carbohydrate - this latter quantity obtained from the Difference columns in Table 7) to the total metabolizable energy intake.

Tables 11 and 12 show the results of fatty acid analyses in the whole carcass of fish from some specific treatments sampled at the termination of the 1979 experiment.

ACKNOWLEDGEMENTS

Rose Curtis, Dianne Plotnikoff, Bakhshish Dosanjh, Jack McBride, John Blackburn, Bill Damon, Tom Buckley, John Davidson, and Ian McCallum have all assisted in various ways during the experiment and are herewith thanked, as are Pat Cowie who typed the manuscript, and Maureen Palmer and staff who prepared the Micom version.

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Table 1a. Composition of diets used in 1979.

Ingredients (g/kg, DW)[a]	Diet (% Protein:% Lipid (DW))[a]				
	42:13	32:8	52:8	32:18	52:18
Herring meal (C.P.[b] = 78.1%)	259.8	197.9	322.3	197.9	322.3
Poultry-by-product meal (C.P. = 73.6%)	87.8	66.9	108.9	66.9	108.9
Feather meal (C.P. = 90.3%)	49.3	37.5	61.1	37.5	61.1
Blood flour (C.P. = 95.9%)	43.4	33.0	53.8	33.0	53.8
Soybean meal (C.P. = 52.4%)	114.2	86.9	141.5	86.9	141.5
Shrimp meal (C.P. = 40.3%)	50.1	50.1	50.0	50.1	50.0
Dextrin	161.2	317.6	119.4	217.7	19.4
Vitamin supplement[c]	37.7	37.7	37.7	37.7	37.7
Herring oil-stabilized[d]	94.2	62.4	25.9	162.4	125.9
Soybean lecithin	10	10	10	10	10
Mineral supplement[e]	30.6	30.6	30.6	30.6	30.6
Carboxymethylcellulose	20	20	20	20	20
Kelp meal	7.2	7.2	7.2	7.2	7.2
DL-Methionine	5.4	4.1	6.7	4.1	6.7
Calcium phosphate monobasic	24.2	33.1	-	33.1	-
Ascorbic acid (ethocel coated)	1.26	1.26	1.26	1.26	1.26
50% choline chloride	3.63	3.63	3.63	3.63	3.63

[a]Dry weight basis.

[b]Crude protein.

[c]The vitamin supplement supplied the following levels of nutrients/kg of dry diet: vitamin A acetate 10512 IU; cholecalciferol 1051 IU; DL-alpha-tocopherylacetate 631 IU; menadione sodium bisulfite complex 84.1 mg; D-calcium pantothenate 172.2 mg; pyridoxine-HCl 38.3 mg; riboflavin 63 mg; niacin 315 mg; folic acid 21.0 mg; thiamine HCl 35.4 mg; biotin 3.15 mg; cyanocobalamin 63 µg; inositol 420 mg.

[d]Herring oil was stabilized with 0.33% butylated hydroxyanisole-butylated hydroxytoluene (BHA-BHT; 1:1).

[e]Refer to Table 2 for information on dietary mineral supplements.

Table 1b. Composition of diets used in 1980.

Ingredients (g/kg, DW)[a]	Diet (% Protein:% Lipid (DW))				
	42:13	42:19.75	42:6.25	55.5:13	28.5:13
Herring meal (C.P.[b] = 72.2%)	267.7	267.7	267.7	346.0	190.7
Poultry-by-product meal (C.P. = 71.9%)	85.5	85.5	85.5	110.6	60.9
Feather meal (C.P. = 89.1%)	47.6	47.6	47.6	61.5	33.9
Blood flour (C.P. = 90.6%)	43.7	43.7	43.7	56.5	31.1
Soybean meal (C.P. = 52.6%)	108.2	108.2	108.2	139.7	77.1
Shrimp meal (C.P. = 36.0%)	53.3	53.3	53.3	68.9	38.0
Dextrin	172.8	111.8	233.8	26.3	312.0
Vitamin supplement[c]	37.7	37.7	37.7	37.7	37.7
Herring oil-stabilized[d]	84.5	145.5	23.5	71.1	97.6
Soybean lecithin	10	10	10	10	10
Mineral supplement[e]	30.6	30.6	30.6	30.6	30.6
Carboxymethylcellulose	20	20	20	20	20
Kelp meal	7.44	7.44	7.44	9.59	5.29
DL-Methionine	5.14	5.14	5.14	6.64	3.66
Calcium phosphate monobasic	20.92	20.92	20.92	-	-
Calcium phosphate dibasic	-	-	-	-	46.6
Ascorbic acid (ethocel coated)	1.26	1.26	1.26	1.26	1.26
50% choline chloride	3.63	3.63	3.63	3.63	3.63

OMP-2[f]	
Ingredients	g/kg as fed
Fish meal	280-300
Cottonseed meal	170
Wheat germ meal	40
Dried whey product	50
Shrimp or crab meal	40
Corn distiller's dried solubles	20- 40
Vitamin premix	15
Wet fish	300
Herring or soybean oil, antioxidant	60
Choline chloride (liquid, 70% product)	5

[a]Dry weight basis.

[b]Crude protein.

[c]Refer to Table 1a for details of vitamin supplement.

[d]Refer to Table 1a for details of antioxidants.

[e]Refer to Table 2 for information on dietary mineral supplements.

[f]Moore Clarke Co., La Conner, Washington, U.S.A. Manufacturer's stated contents.

Table 2. Composition of mineral supplements in each diet used in 1979 or 1980. Refer to Tables 1a and 1b for additional information.

Mineral (mg/kg dry diet)	Diet (%Protein:%Lipid)									
	32:8	52:8	32:18	52:18	28.5:13	55.5:13	42:6.25	42:19.75	42:13	42:13[a]
Ca (as $CaCO_3$)	4010	-	4010	-	-	-	-	-	2079	-
(as $Ca(H_2PO_4)_2 \cdot H_2O$)	-	2408	-	2408	-	-	-	-	-	-
P (as $Ca(H_2PO_4)_2 \cdot H_2O$)	-	3723	-	3723	-	-	-	-	-	-
(as $K_2HPO_4 \cdot 3H_2O$)	-	-	-	-	-	1843	-	-	-	-
Mg (as $MgSO_4$)	1796	1335	1796	1335	1698	658	1181	1181	1567	1181
Mn (as $MnSO_4 \cdot H_2O$)	31.3	26.8	31.3	26.8	30.4	24.3	27.4	27.4	29.0	27.4
Zn (as $ZnSO_4 \cdot 7H_2O$)	27	1.1	27	1.1	36	9.6	22.8	22.8	14.8	22.8
Co (as $CoCl_2 \cdot 6H_2O$)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Cu (as $CuSO_4$)	6.76	3.76	6.76	3.76	10.7	6.22	8.57	8.57	5.28	8.57
Fe (as $FeC_6H_5O_7 \cdot 5H_2O$)	231	22.5	231	22.5	229	64	146	146	127	146
I (as KI)	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Na (as NaCl)	3242	2109	3242	2109	4877	962	2937	2937	2679	2937

[a]This diet manufactured in 1980.

Table 3. Proximate composition of diets used in 1979 or 1980. Refer to Tables 1a and 1b for additional information.

Diet[a]		Analytical results[a]								
Protein %	Lipid %	Moisture %	Protein %	Fiber %	Lipid %	NFE[b] %	Ash %	Gross energy[c] (kcal/g)	ME[d] (kcal/g)	Digestible protein[e] (mg/dig. kcal)
32	8	7.2	32.6	3.6	10.7	41.5	11.6	4.53	3.65	80.4
52	8	7.8	51.2	4.1	9.8	22.0	13.0	4.73	3.82	120.6
32	18	6.7	31.5	3.6	19.4	33.3	12.2	4.97	4.06	69.8
52	18	7.3	49.2	4.1	18.5	15.6	12.6	5.19	4.19	105.7
28.5	13	8.7	31.5	3.3	12.2	41.1	11.9	4.60	3.72	76.2
55.5	13	8.1	54.7	4.4	13.2	14.4	13.3	4.95	4.01	122.8
42	6.25	8.1	42.4	3.8	7.7	34.8	11.3	4.54	3.61	105.7
42	19.75	8.4	43.1	3.8	17.3	23.8	11.8	5.05	4.13	94.4
42	13	7.3	41.9	3.8	14.0	28.2	12.1	4.85	3.91	96.4
42	13[f]	8.0	42.3	3.8	12.8	29.9	11.2	4.82	3.88	98.1
OMP[g]		28.0	48.2	3.6	16.5	19.5	12.2	5.09	3.98	109.0

[a]% dry matter (except moisture).

[b]Nitrogen Free Extract, estimated (approximates carbohydrate).

[c]Gross caloric content of diets estimated ascribing 5.7 kcal/g crude protein; 9.5 kcal/g crude lipid, and 4.0 kcal/g carbohydrate.

[d]Metabolizable energy content of diets. Estimated ascribing 4.52 kcal/g crude protein; 9.0 kcal/g crude lipid, 3.2 kcal/g dextrin, 1.6 kcal/g raw starch and 4.0 kcal/g carbohydrate from animal sources.

[e]90% of protein (%) / ME (kcal/g).

[f]This diet was made up in 1980; analysis differs slightly from the one (1979) immediately preceeding.

[g]Oregon Moist Pellet (OMP) diet included for comparison.

Table 4. Mineral content (g/kg dry diet) of each diet used in 1979 or 1980[a].

Minerals	Diet (% Protein:% Lipid)										
	32:8	52:8	32:18	52:18	28.5:13	55.5:13	42:6.25	42:19.75	42:13	42:13[b]	OMP[c]
Calcium (Ca)	29.0	26.6	27.1	27.1	29.4	30.0	26.5	28.0	27.4	27.2	32.5
Phosphorus (P)	16.1	16.0	17.3	17.0	16.8	16.2	16.0	16.6	15.7	15.7	16.6
Magnesium (Mg)	2.90	2.93	3.14	3.06	2.60	2.54	2.58	2.63	2.86	2.66	2.87
Copper (Cu)	0.016	0.016	0.016	0.015	0.020	0.019	0.020	0.020	0.017	0.020	0.012
Iron (Fe)	0.465	0.378	0.535	0.393	0.436	0.435	0.390	0.430	0.397	0.480	0.203
Manganese (Mn)	0.038	0.038	0.040	0.038	0.034	0.038	0.038	0.036	0.036	0.036	0.020
Zinc (Zn)	0.066	0.057	0.062	0.055	0.069	0.069	0.066	0.069	0.064	0.070	0.072
Cobalt (Co)	0.0043	0.0038	0.0050	0.0039	-	-	-	-	0.0036	-	-
Sodium (Na)	10.6	11.7	11.2	12.4	11.4	10.5	10.9	11.7	11.2	10.8	5.47
Aluminum (Al)	0.057	0.040	0.064	0.047	0.024	0.027	0.017	0.019	0.050	0.021	0.034
Barium (Ba)	0.0065	0.0072	0.0068	0.0074	0.0028	0.0047	0.0037	0.0041	0.0068	0.0038	0.0023
Silicon (Si)	0.145	0.114	0.249	0.200	0.136	0.170	0.075	0.102	0.130	0.097	0.124
Strontium (Sr)	0.124	0.129	0.131	0.131	0.104	0.178	0.137	0.147	0.123	0.138	0.203
Ca:P	1.8	1.7	1.6	1.6	1.8	1.8	1.6	1.7	1.7	1.7	2.0
Ca:Mg	10	9.1	8.6	8.8	11.3	11.8	10.3	10.6	9.6	10.2	11.3
P:Mg	5.6	5.5	5.5	5.6	6.5	6.4	6.2	6.3	5.5	5.9	5.8

[a]Levels of dietary minerals determined by plasma spectroscopy (Higgs et al., 1982).

[b]This diet manufactured in 1980.

[c]Oregon Moist Pellet (OMP) diet included for comparison.

Table 5. Assigned treatment levels and mean temperature, stock size and mortalities for the two replicates in 1979 and 1980.

Treatment Level			First replicate: 1				Second replicate: 2			
Protein %	Lipid %	Temp °C	Mean temp °C	Initial[a] n	Final n	Mort-alities	Mean temp °C	Initial[a] n	Final n	Mort-alities
32	8	8	7.8	96	94	2	8.0	91	89	2
52	8	8	7.9	95	92	3	8.1	93	91	2
32	18	8	8.0	91	91	0	8.0	94	94	0
52	18	8	8.0	92	92	0	8.1	93	92	1
32	8	18	18.1	93	92	1	18.2	85	84	1
52	8	18	18.0	94	93	1	18.1	91	89	2
32	18	18	18.0	93	92	1	18.2	94	93	1
52	18	18	18.1	92	92	0	18.2	84	84	0
28.5	13	13	13.1	94	94	0	13.1	95	95	0
55.5	13	13	13.1	95	94	1	13.0	95	95	0
42	6.25	13	13.0	94	93	1	13.1	95	95	0
42	19.75	13	13.1	94	94	0	13.1	95	94	1
42	13	6.25	7.0	94	94	0	7.0	62[b]	62	0
42	13	19.75	19.1	95	95	0	19.1	95	95	0
42	13	13	13.1	93	93	0	13.1	95	95	0
42	13	13	13.1	92	92	0	13.1	95	94	1
42	13	13	13.1	95	94	1	13.1	94	94	0
[c]OMP		13	13.1	97	97	0	13.1	94	94	0

[a]100 fish/tank prior to sampling for proximate analysis.

[b]38 fish escaped down drain prior to start.

[c]OMP, see legend, Table 3.

Table 6. Mean fish weights and specific growth rates of the 2 replicates in 1979 and 1980.

Treatment Level			Mean wet weights (g)						Specific growth rate (G) %day^{-1}		Duration (d)[e]
			Initial		Final		Gain				
Protein %	Lipid %	Temp °C	1	2	1	2	1	2	1	2	
32	8	8	2.38	2.40	4.97	5.09	2.59	2.69	1.25	1.27	59
52	8	8	2.62	2.62	6.20	5.84	3.58	3.22	1.46	1.36	59
32	18	8	2.69	2.59	5.63	5.60	2.94	3.01	1.25	1.31	59
52	18	8	2.55	2.59	5.63[a]	5.93	3.08	3.34	1.34	1.40	59
32	8	18	3.51	3.67	8.68	9.19	5.17	5.52	1.53	1.56	59
52	8	18	3.70	3.69	9.23	9.67	5.53	5.98	1.55	1.63	59
32	18	18	3.50	3.71	9.70	9.79	6.20	6.08	1.73	1.64	59
52	18	18	4.08	3.78	10.91[b]	11.37	6.83	7.59	1.67	1.87	59
28.5	13	13	3.56	3.36	10.78	9.57	7.22	6.21	1.65	1.56	67
55.5	13	13	3.51	3.52	12.13	12.77	8.62	9.25	1.85	1.92	67
42	6.25	13	3.55	3.63	10.77	11.22	7.22	7.59	1.66	1.68	67
42	19.75	13	3.78	3.62	12.72	11.45	8.94	7.83	1.81	1.72	67
42	13	6.25	2.93	2.99	7.33	7.74	4.40	4.75	1.37	1.42	67
42	13	19.75	3.87	3.94	9.70	10.60	5.83	6.66	1.37	1.48	67
42	13	13	3.46	3.60	9.65	9.48	6.19	5.88	1.74	1.64	59
42	13	13	3.55	3.24	9.50	9.46	5.95	6.22	1.67	1.82	59
[c]42	13	13	3.61	3.72	10.26	12.39	6.65	8.67	1.56	1.80	67
[d]OMP		13	3.50	3.56	11.67	12.02	8.17	8.46	1.80	1.82	67

[a]Interpolated point.

[b]Extrapolated point. Questionable original point was 9.83 with G=1.49.

[c]1980 sample; 1979 replicates on the 2 lines immediately preceeding.

[d]OMP, see legend, Table 3.

[e]59 days duration in 1979, 67 days in 1980.

Table 7. Initial and final whole body proximate composition (dry weight basis).

Treatment Level			Initial sample						Final sample					
Protein %	Lipid %	Temp °C	n	Moisture %	Protein %	Lipid %	Ash %	Difference %	n	Moisture %	Protein %	Lipid %	Ash %	Difference %
32	8	8	10	78.8	71.5	15.5	9.6	3.4	5	74.6	61.6	31.2	9.0	-1.8
52	8	8	-	79.2	70.7	15.7	9.3	4.3	-	76.3	66.0	23.5	9.1	1.4
32	18	8	-	78.9	74.9	15.1	9.9	0.2	-	73.3	55.6	36.2	7.7	0.5
52	18	8	-	79.2	72.3	14.7	10.1	2.9	-	74.9	61.4	30.1	8.6	-.1
32	8	18	-	77.5	66.1	19.5	11.4	3.0	-	71.2	52.3	38.7	9.1	-.1
52	8	18	-	78.2	69.2	17.5	10.7	2.6	-	70.5	54.2	36.1	8.0	1.7
32	18	18	-	77.5	67.8	17.8	11.2	3.2	-	68.8	47.5	44.4	7.5	0.6
52	18	18	-	77.8	68.1	19.5	11.4	1.0	-	70.2	51.7	40.1	7.8	0.4
28.5	13	13	20[b]	75.5	64.1	22.3	8.7	4.9	-	69.3	47.2	42.7	6.4	3.7
55.5	13	13	-[b]	-	-	-	-	-	-	70.3	53.7	36.7	7.6	2.0
42	6.25	13	-[b]	-	-	-	-	-	-	72.0	55.4	32.7	7.5	4.4
42	19.75	13	-[b]	-	-	-	-	-	-	68.2	48.2	43.5	6.0	2.3
42	13	6.25	10	76.5	64.7	21.2	10.4	3.7	-	72.8	56.8	33.3	7.4	2.5
42	13	19.75	-	76.2	67.4	22.7	9.9	0	-	67.8	46.1	43.4	6.9	3.6
42	13	13	-	78.0	69.5	16.5	9.9	4.1	-	72.1	54.3	35.6	7.7	2.4
[a]42	13	13	-[b]	75.5	64.1	22.3	8.7	4.9	-	70.2	51.9	39.4	7.6	1.6
[c]OMP		13							-	68.8	48.4	41.1	6.3	4.1

[a]1980 sample; 1979, line immediately preceeding

[b]Pooled sample totalling 20 fish on basal diet from all 13°C tanks (1980).

[c]OMP, see legend, Table 3.

Table 8. Mean dry weight gain, dry feed intake and feed conversion for the two replicates.

Treatment Level			Gain g/fish		Consumption g feed/fish		Conversion (Gain/Consumption) X 100%	
Protein %	Lipid %	Temp °C	1	2	1	2	1	2
32	8	8	.76	.78	4.0	4.1	19.0	19.0
52	8	8	.92	.84	4.5	4.1	20.4	20.5
32	18	8	.93	.95	4.3	4.2	21.6	22.6
52	18	8	.88	.95	3.6	3.8	24.4	25.0
32	8	18	1.71	1.82	7.6	8.4	22.5	21.7
52	8	18	1.92	2.05	7.7	8.3	24.9	24.7
32	18	18	2.24	2.22	8.7	8.4	25.7	26.4
52	18	18	2.35[a]	2.55	8.5	8.3	27.6	30.7
28.5	13	13	2.44	2.12	9.9	8.6	24.6	24.7
55.5	13	13	2.74	2.93	9.6	10.2	28.5	28.7
42	6.25	13	2.15	2.25	9.9	10.8	21.7	20.8
42	19.75	13	3.12	2.75	10.3	9.6	30.3	28.6
42	13	6.25	1.31	1.40	6.4	7.3	20.5	19.2
42	13	19.75	2.20	2.48	8.6	9.3	25.6	26.7
42	13	13	1.93	1.85	7.0	7.1	27.6	26.1
42	13	13	1.87	1.93	6.7	7.8	27.9	24.7
42	13	13	2.17	2.78	8.6	10.4	25.2	26.7
[b]OMP		13	2.78	2.88	9.8	10.4	28.4	27.7

[a]Extrapolation, see legend, Table 6.

[b]OMP, see legend, Table 3.

Table 9. Effect of treatments on three measures of protein utilization (replicated).

Treatment Level			ANPU[a](%)		PER[b]		mg protein gain per kcal ME[c] fed	
Protein %	Lipid %	Temp °C	1	2	1	2	1	2
32	8	8	32.2	31.9	.59	.58	28.7	28.6
52	8	8	25.1	25.2	.40	.40	33.6	33.7
32	18	8	29.9	31.4	.69	.71	23.3	24.3
52	18	8	27.6	28.4	.50	.51	32.4	33.2
32	8	18	31.9	30.9	.69	.67	28.5	27.6
52	8	18	23.2	23.1	.48	.48	31.1	31.0
32	18	18	33.1	33.4	.82	.84	25.7	25.9
52	18	18	25.2[d]	28.7	.56[d]	.62	29.7[d]	33.6
28.5	13	13	32.3	31.8	.78	.78	27.4	26.9
55.5	13	13	26.3	26.5	.52	.53	35.8	36.2
42	6.25	13	26.7	25.7	.52	.49	31.4	30.2
42	19.75	13	30.3	28.7	.70	.66	31.8	29.9
42	13	6.25	25.2	24.1	.48	.46	27.5	26.3
42	13	19.75	22.4	24.0	.60	.63	24.4	26.2
42	13	13	31.5	29.9	.66	.63	33.7	32.0
42	13	13	31.7	28.6	.67	.59	34.0	30.6
42	13	13	28.1	30.3	.60	.63	30.6	33.0
[e]OMP		13	25.6	25.0	.59	.57	31.0	30.3

[a]Apparent Net Protein Utilization: (Crude protein gain (g)/ crude protein intake (g)) x 100.

[b]Protein Efficiency Ratio: Dry weight gain (g)/crude protein intake (g).

[c]Metabolizable Energy, see legend, Table 3.

[d]Extrapolation, see legend, Table 6.

[e]OMP, see legend, Table 3.

Table 10. Effect of treatments on lipid and energy utilization (replicated).

Treatment Level			Lipid conversion (%)[a]		Energy Utilization[b]	
Protein %	Lipid %	Temp °C	1	2	1	2
32	8	8	73.6	73.1	37.2	36.8
52	8	8	60.4	55.9	33.6	34.0
32	18	8	54.4	55.6	37.9	39.2
52	18	8	52.6	53.0	40.7	41.3
32	8	18	55.1	53.1	44.2	43.2
52	8	18	111.8	109.4	45.0	44.4
32	18	18	71.9	74.4	47.2	48.4
52	18	18	71.4[c]	77.3	46.9[c]	51.6
28.5	13	13	101.4	102.4	47.2	47.3
55.5	13	13	89.0	89.0	48.3	48.5
42	6.25	13	104.6	100.5	39.5	37.8
42	19.75	13	87.2	83.6	52.9	50.1
42	13	6.25	58.6	59.2	35.5	33.6
42	13	19.75	103.9	107.2	46.8	48.8
42	13	13	83.9	81.6	48.0	46.2
42	13	13	86.3	75.0	48.9	43.1
42	13	13	91.7	94.0	46.2	48.3
OMP[d]		13	80.5	78.4	49.7	48.4

[a](Lipid gain/lipid consumed) X 100.

[b](Crude energy gain (kcal) per kcal ME intake) x 100 [ME, see legend, Table 3].

[c]Extrapolation, see legend, Table 6.

[d]OMP, see legend, Table 3.

Table 11. Whole body fatty acid composition of neutral lipid for selected treatments from final sample, 1979.

Treatment Level			Fatty Acid									
Protein %	Lipid %	Temp °C	14:0	16:0	16:1n7	17:0	17:1	18:0	18:1n9	18:2n6	18:3n6	18:3n3
32	8	8	2.9	12.8	8.2	1.7	1.9	3.0	25.2	7.5	1.6	1.8
52	8	8	2.6	13.2	8.3	1.3	1.5	3.4	28.3	9.0	1.8	1.6
32	18	8	3.8	12.8	8.2	1.5	1.3	2.4	26.9	5.9	0.9	1.3
32	8	18	3.4	16.2	9.9	1.1	1.1	3.3	29.7	6.5	1.2	1.1
52	8	18	3.0	17.3	9.8	0.9	1.0	4.5	32.5	7.2	1.4	1.1
32	18	18	3.3	13.2	7.8	1.4	1.3	2.8	25.8	5.0	1.0	1.4

Table 11. (cont'd).

Treatment Level			Fatty Acid									
Protein %	Lipid %	Temp °C	18:4n3	20:1n9	20:2n6 (n9?)	20:3n9	20:4n6	20:5n3	20:1n9	22:4n6	22:5n3	22:6n3
32	8	8	1.9	6.8	0.9	0.9	1.7	2.8	7.2	0.6	0.6	3.3
52	8	8	1.6	5.5	0.8	0.8	1.6	2.1	5.5	2.0	0.3	3.5
32	18	8	1.5	8.5	0.6	0.5	1.1	3.4	8.5	1.0	0.7	4.6
32	8	18	1.3	5.8	0.6	0.6	1.0	2.2	5.3	0.5	0.5	3.6
52	8	18	1.1	4.3	0.6	0.6	1.0	1.6	3.9	0.3	0.3	3.2
32	18	18	1.6	7.3	0.7	0.8	1.5	3.5	8.7	1.2	1.2	4.4

Table 12. Whole body fatty acid composition of phopholipid for selected treatments from final sample, 1979.

Treatment Level			Fatty Acid									
Protein %	Lipid %	Temp °C	14:0	16:0	16:1n7	17:0	17:1	18:0	18:1n9	18:2n6	18:3n6	18:3n3
32	8	8	1.1	21.1	3.9	0.6	0.1	4.3	12.7	3.7	0.1	0.3
52	8	8	1.0	17.8	4.3	1.1	1.4	4.3	13.3	4.8	0.8	1.2
32	18	8	1.1	17.8	4.3	1.6	1.5	4.2	11.4	3.9	-	1.4
32	8	18	1.1	18.7	5.7	1.2	1.7	4.9	14.7	4.4	0.9	1.3
52	8	18	0.9	17.3	5.1	1.5	2.0	6.6	12.8	5.1	1.2	1.6
32	18	18	0.9	18.0	4.1	1.5	2.0	4.5	10.3	3.5	1.1	2.1

Table 12. (cont'd)

Treatment Level			Fatty Acid									
Protein %	Lipid %	Temp °C	18:4n3	20:1n9	20:2n6 (n9?)	20:3n9	20:4n6	20:5n3	22:1n9	24:0?	22:5n6	22:5n3	22:6n3
32	8	8	0.7	1.6	0.7	0.3	2.3	7.0	0.5	0.9	0.5	1.6	34.8
52	8	8	1.0	2.0	1.1	1.1	3.1	5.3	1.9	0.3	1.0	1.1	28.6
32	18	8	2.0	2.7	1.3	0.6	3.0	8.5	2.0	1.3	0.8	1.4	28.1
32	8	18	1.6	2.2	1.5	1.4	3.2	5.8	1.7	-	0.4	1.3	22.2
52	8	18	0.9	2.1	2.1	1.6	3.8	6.1	2.2	1.6	0.8	1.1	20.0
32	18	18	1.4	2.4	0.9	1.1	3.3	7.6	1.6	-	0.9	1.9	24.1